Jeff Lacy.

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MULTIWIRE PROPORTIONAL COUNTER DEVELOPMENT

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PROGRESS TO DATE

In the fifth quarter of this contract, most of our effort has been directed toward a test run at the Bevatron, which was made in mid-January. The purpose of this run was to check the chamber with relativistic alpha particles and neon nuclei ($Z = 10$). Data were obtained with alphas and with carbon nuclei ($Z = 6$), since the attempts to accelerate neon were not successful. The data are presently being analyzed.

The winding machine mentioned in the last report was completed, and used in the construction of a new chamber.

Theoretical studies were initiated to try to understand the reason for the uncertainty in the position measurement.

Bevatron Run

In our proposal for the run with relativistic heavy ions, the purpose was stated as follows: "The purpose of the run will be to investigate the character of the signals induced in an electromagnetic delay line capacitively coupled to the wire cathode plane of a multiwire proportional chamber. In particular, we wish to study these signals and the behavior of the readout electronics as a function of associated δ-ray production. These measurements are important in assessing the effect of δ-ray background on the spatial resolution attainable for the primary ions. The results of these tests will aid us in designing multiwire proportional chambers and readout systems for use as spatial detectors in a superconducting magnetic spectrometer experiment planned by the Alvarez group for cosmic ray nuclei and electrons on the High Energy Astronomy Observatory spacecraft. The use of the Bevatron high energy heavy ion beam is the only way in which the δ-ray background effects on the chamber can be evaluated in a situation approximating that which will be encountered during this experiment."

The MWPC, delay line, preamflifier, and discriminators were shipped to Berkeley and set up at the Bevatron. The Alvarez group provided a scintillation counter telescope, chamber gases, logic modules, power supplies, a dual beam oscilloscope and scope camera.

Pulses were taken from a dealy line coupled to one of the cathodes. Runs were made both with 75% argon - 25% CO_2 and with 79.5% argon - 20% isobutane - 0.5% Freon. Pulse height spectra were measured, and oscilloscope pictures were taken. The scope was triggered by the scintillation counter telescope, and pulses from the MWPC were displayed.

About 170 pictures were made with a 2.1 GeV/nucleon beam of alpha particles, while the Bevatron was being tuned for the heavy ion beam. When the machine was operated with neon in the ion source, it was found that that beam was nearly pure C^{12}. About 800 pictures were taken with this beam, both with and without absorbers in front of the chamber. These pictures are presently being analyzed.

<u>Winding Machine</u>

Construction of the winding machine was finished in this quarter. A picture is shown in Figure 1. The lead screw, and the threaded rods on induced on the two adjacent anode wires, are equal in a symmetric chamber, regardless of the location of the primary ionization. With an anode wire of 20μ diameter, this means that the discharge spreads 30 to 50μ in each direction around the wire. It seems reasonable to assume that the discharge spreads at least this far along the wire.

An upper bound to the discharge region is given by the measurements of the relative response of different cathode strips, when the location of a primary event is known. The results of this measurement were given in the last quarterly report (29 October 1971). The f.w.h.m. of the measured distribution was 11 mm.

The expected distribution varies with position as:

$$\frac{1}{L^2 + x^2}$$

where L is the distance from anode to cathode. The f.w.h.m. is 2L or about 10 mm in our chamber. Since the entire f.w.h.m. can be accounted for on the basis of a point discharge, the discharge cannot spread more than a few millimeters.

If the discharge spreads equally in both directions, this will have no effect on the measurement of position. However, any asymmetry in the distribution of ionization will result in jitter in the position measurement. The most important mechanism of spreading is probably ultraviolet photons. If these have ranges of the order of a millimeter in the gas, then we can deduce that the product, number of photons times probability of creating an ion, is not large--otherwise there would be a Geiger-Muller discharge. In this case, we could expect an asymmetry in the distribution resulting in a displacement of the centroid of a fraction of a millimeter.

Figure 1. Winding Machine

The ionization potential of argon is 15.755 eV, corresponding to a wavelength of 787 Å. At wavelengths shorter than this, the absorption cross-section is 2 to 5 x 10^{-17} cm^2. The corresponding mean free path is 10 - 25 microns. This is too short to give an appreciable asymmetry in the charge distribution.

At wavelengths longer than 787 Å, the absorption cross-section decreases below 10^{-18} cm^2. At these wavelengths, the probability of ionizing an argon atom also decreases markedly. Ionization is possible now only if the energy levels of the atom have been perturbed by a collision with another atom. The process

$$h\nu + Ar + Ar \longrightarrow Ar_2^+ + e$$

permits ionization at longer wavelengths, at which the mean free path may be of the order of a millimeter. This is sufficiently long to account for a significant displacement of the centroid of the discharge.

Summary

The most likely candidate for the effect which limits the spatial resolution to about 0.2 mm (1σ) is the spread of the discharge along the wire. If so, it should be possible to minimize this by proper selection of the counter gas.

We are pursuing our investigation of the mechanism responsible for the spread of the discharge both analytically and in the laboratory.

Electronic Circuits

A number of improvements have been made in the electronic circuits since our last report. These are reflected in the schematic (Figure 1).

... wire is wound, have 13 threads per inch: the spacing is 1.954mm, ... taken to be a nominal 2mm. The wire tension is controlled by a ... brake, and measured by a calibrated spring balance.

... machine was used to wind MWPC #3 (see next paragraph). For the ... planes, it was motor driven. For the anode planes, it was turned ... This allowed a more accurate control of the tension, and also ...ted a spacing of 4mm rather than the 2mm for which the machine is ...tly set.

The machine is now being modified to wind delay lines as well as MWPC wire planes.

...ratory Model MWPC #3

In preparation for the run at the Bevatron, another MWPC was constructed. The anode plane was an array of 20-micron tungsten wires spaced 4mm apart. The two cathode planes were wound of 250-micron stainless steel wires, 2mm apart, 5mm on either side of the anode plane. The frame is of NEMA G10, and the top and bottom covers are of mylar. Wires were used for the cathode planes in order to avoid distortion due to internal pressure when the planes were plated on the mylar windows.

The chamber was assembled and tested, and then shipped to Berkeley as a spare. It was not needed for the Bevatron runs.

...sition Uncertainty

In our consideration of the uncertainty in the location of an ionizing event in the chamber, we have been unable to locate any single factor which would limit the standard deviation to approximately 0.2mm. We have considered the following sources of jitter:

(a) Electron diffusion.

(b) Noise in the electronics.

(c) Lateral ranges of ionizing particles in the sensitive volume.

(d) Source width or misalignment.

(e) Delta rays.

(f) Spread of the discharge along the anode wire.

Electron Diffusion

We calculated that, at 2500 volts in 75% argon - 25% isobutane, the r.m.s. diffusion distance is approximately:

$$\langle x \rangle = 150 \text{ microns}$$

in one dimension, for an electron starting from the vicinity of the cathode. The r.m.s. error in position due to diffusion is

$$= \frac{\langle x \rangle}{\sqrt{n}}$$

where n is the number of primary electrons collected.

If there are 240 primary electrons generated by a 5.9 KeV Fe^{55} x-ray, and if all of these are collected, we get

$$\sigma \simeq 10 \text{ microns}$$

which is insignificant compared to the measured values.

We can foresee only one circumstance in which the position error due to electron diffusion would be significant: if an electronegative gas, such as freon, is used in sufficient concentration so in many cases only one or two primary electrons are collected; and if the gain is sufficiently close to saturation so that these events are counted along with the ones in which many primaries are effective.

Our Ortec 109A charge integrating preamplifiers were modified as voltage amplifiers by replacing the one picofarad feedback capacitor with a 100K resistor. The resulting voltage gain is about 50. The delay line signals are therefore no longer integrated and have a characteristics rise time out of the Ortec of about 100 nanoseconds and a decay time of about 200 nanoseconds.

The comparator delay line has been reduced to 65 nanoseconds to give the desired crossing characteristics for the present input signals. The changes were incorporated to improve the possibility of discriminating against δ-rays traversing the chamber at distances greater than $\sim$3 centimeters from the primary. No significant degradation of the spatial resolution was observed with our collimated x-ray source.

The gating for the constant fraction discriminator has been made more reliable by the addition of a Schmidt trigger stage between the 733 amplifier and the first MC 1662 gate. Additional gating was also built into the discriminator as shown on Figure 2 for use with a beam gate input for our Bevatron run and for future accelerator testing. The numerous "pull down" resistors at the nor gate outputs are historical and in most cases can be avoided by substituting the MC 1663 low impedance gates.

The flip-flop, integrator, sample, and analyzer gates are essentially the same as shown on Figure 9 of our last report.

An additional breadboard has been designed and built to enable us to study the spatial resolution as a function of position anywhere in the chamber while preserving the same absolute accuracy in the pulse height analyzer ($\sim$0.1 mm per channel). This is accomplished by scaling and gating a 10MHz crystal controlled oscillator in such a way that finite time intervals are subtracted out of the time separation pulse. The gated early and late mark signals from the discriminators are now fed into these circuits instead of into the flip flop. The output then goes to the integrator and to the pulse height analyzer. Manual binary switches permit removal of time increments in steps of 100 nanoseconds up to 3.1 microseconds. In this manner the circuits may be adjusted so that the analyzer gain can remain fixed and independent of the location of the x-ray source. These measurements were interrupted in order to prepare for the Bevatron tests.

Work Presently Underway

Since the Bevatron run came near the end of the reporting period, the major part of the present effort consists in the reduction of the data, and planning and preparation for the next phase.

Calculations of chamber response as a function of input and applied voltage are underway, in order to understand the phenomenon of pulse height saturation. It appears to us that the assumptions made in the accepted calculation of gain* are not good, and the process of multiplication can be understood better on the basis of a different set of assumptions.

The winding machine (Figure 1) is being modified so as to make it possible to use it for winding delay lines. This involves the installation of a vernier mechanism to match the pitch exactly to the wire diameter. When this is completed, we anticipate that it will be much easier to use for this purpose than a lathe.

* Curran and Craggs, Counting Tubes, Chapter 3; Butterworth, 1949

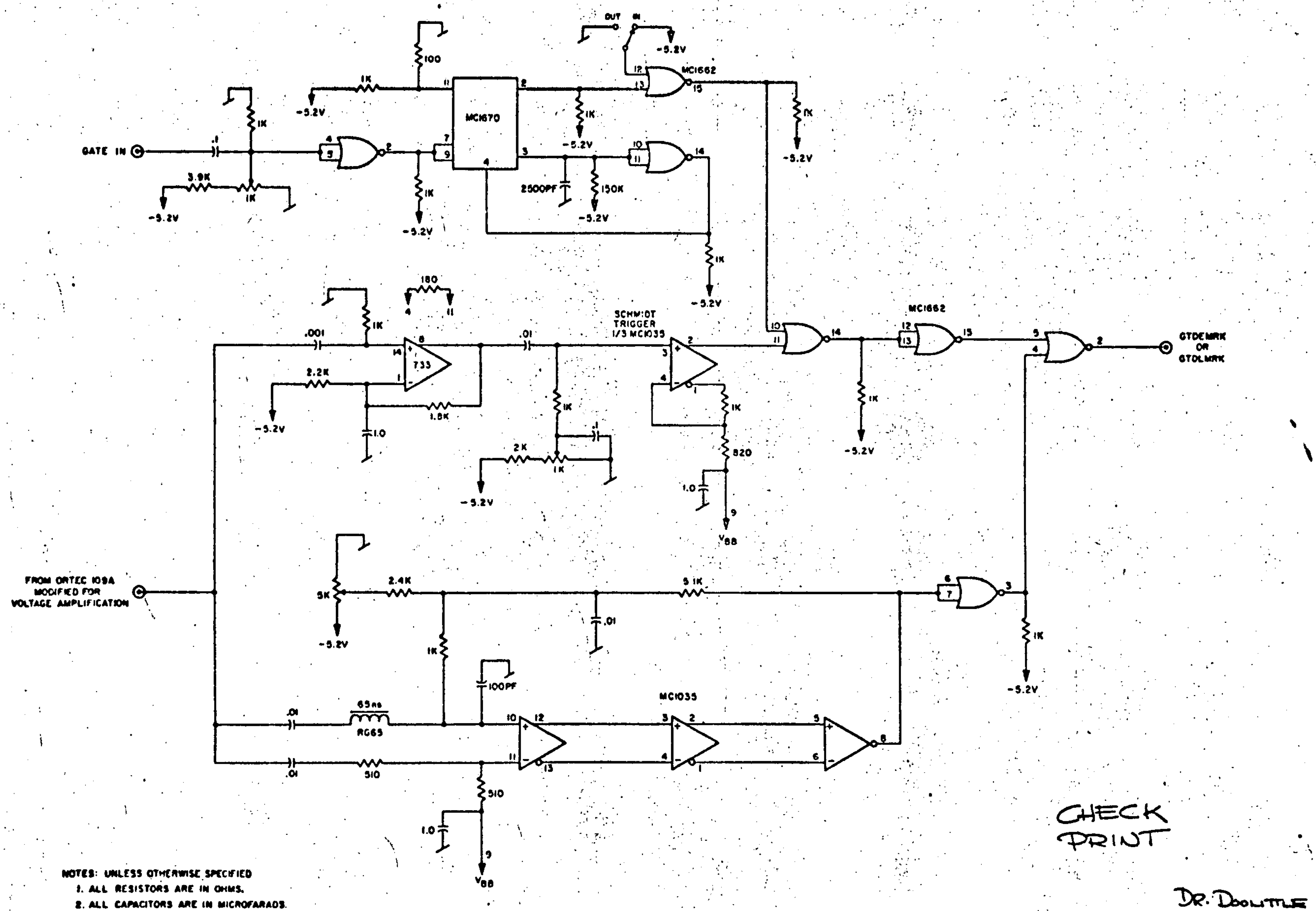

Figure 2. Constant Fraction Discriminator and One-Shot Gate

In the latest set of resolution measurements, the gas was argon-isobutane with no freon. With this mixture, we do not believe that electron diffusion can have contributed significantly to the measured uncertainty in position.

We anticipate that our projected studies of electron capture in electronegative gases, and of the saturation of pulse height, will shed light on the contribution of electron diffusion to the uncertainty in position in argon-isobutane-freon mixtures.

Noise in the Electronics

The contribution of electronic noise can be estimated by using a pulser in place of the chamber. The pulser should reproduce the chamber pulses as closely as possible, and be fed into the delay line through the cathode lands. The experiments which we have performed to date give a fair approximation of the ideal situation, and indicate that the electronic contribution to the jitter is negligible for signals greater than 0.5 volts into the discriminators. This appears at present not to be the limiting factor.

Lateral Extent of Primary Ionization

The source we have used in most measurements of spatial resolution is Fe^{55}, which emits 5.9 KeV x-rays. These are absorbed almost entirely by the argon atoms.

The probability that absorption leads to the emission of an electron from the K shell is:

$$p_K = 0.90$$

and for the L shell:

$$p_L \simeq 0.10$$

The fluorescence yields are:

$$\omega_K = 0.11$$

$$\omega_L = 0.01$$

The probability of escape of the K x-ray is:

$$\varepsilon_K \simeq 0.9$$

Eighty-one percent of the time we get K-shell absorption followed by de-excitation via the Auger effect. This will result in the production of two 3-KeV electrons at the point of interaction.

Eight-to-nine percent of the time there is one 3-KeV electron (escape peak).

Zero-to-one percent of this time there are two $\sim$3-KeV electrons at different points in the chamber (reabsorption of the Ar K x-ray). The mean free patch of the Ar K x-ray is $\lambda = 3.8$ cm; the two points will, therefore, in general be several millimeters apart.

Ten percent of the time there are one 5.65-KeV electron and one 0.24-KeV electron (L-shell absorption).

The range of a 3-KeV electron in the gas is about 0.1mm. For the two-electron case, if the directions of emission are not correlated, the r.m.s. distance along one axis between the point of origin and the centroid of the ionization distribution is 20 microns. If there is only one 3-KeV electron, this distance becomes 30 microns. These two cases between them cover 90% of the events. Since the value of σ, the r.m.s. position error, is in general determined on the basis of the width of the curve at the 50% or 60% point, it will not be affected by the other 10% of the cases. it appears that electron ranges do not contribute significantly to the measured value of σ.

Problem Areas

One of the problems which we face at present is the effect of delta rays on the measurement of track position. We expect much valuable information from a study of the pulse shape in the carbon run at the Bevatron. Based on this study, we will attempt to optimize the operating parameters of the chamber and the timing electronics.

Another problem, closely associated with the first, is pulse height saturation. As we have mentioned earlier in the report, this effect is being studied.

New Technology

There are no new technology developments to report.